Technological and Scientific Resources

By KARL T. COMPTON

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THE subject of this article is exceedingly pertinent at the present time when the scientific and technological resources of the Nation are being marshaled for national defense.

Ten years ago when the depression had upset confidence in the very foundation of our economic structure, we were told by some that unrestrained enterprise and technological progress had overbuilt production way beyond our capacity to consume the goods produced. We technologists wondered if we had any right to be alive, let alone to do our job, as we heard and read the theories of those who believed that higher standards of living are assured by curbing production, not stimulating it; by making production more expensive rather than cheaper; by distributing wealth by laws without much thought of how this wealth can be created.

MEN WITH TECHNICAL TRAINING NEEDED

Today the contrast is startling. No need in the country is more urgent than that for more and better technically trained men, no objective more important than increased productive power, and the pure scientist is suddenly found to be very useful, as is always so when affairs get away from conventional paths. Perhaps it is not pleasant to think that this change has come because of war. I believe that it was coming in spite of the war, and that the present defense activity has only switched into temporary channels and stimulated a movement which was already under way. Witness, for example, the scientific research program of the National Association of Manufacturers now in its fourth year; the New Products Committee program of the New England Council; the recent rapid increase in the number of industrial research laboratories; and the activities of the National Resources Planning Committee of the Federal Government. These are some of the signs, independent of the war, that people in important places have reacted against the panicky confusion of ten years ago and that they see in technological progress, in development and in production, essential elements of national prosperity —prerequisites to any and all sound schemes for the economic betterment of every social group.

But much has already been said and written about scientific and technological resources in normal times, so let us turn at once to the more interesting and timely discussion of these resources as related to national defense. The first important thing to keep in mind is that our technological and scientific resources are primarily questions of trained personnel and their organization. Funds for operation of laboratories, equipment for laboratories, and even the construction of laboratories can be secured on relatively short order by the vote of necessary funds whenever an emergency is important enough to demand such action, but scientifically and technically trained personnel cannot be quickly obtained and therefore it is the personnel side of our technological and scientific resources which becomes the bottleneck of our effort in any extreme emergency like the present one. Consequently the great problem of national defense as it concerns our technological and scientific resources is the problem of organizing existing personnel, of quick supplementary training of some additional personnel, and of continuing the funda-

mental training of still further personnel, all in the manner to be most effective in meeting the emergency.

AGENCIES ALREADY IN EXISTENCE

We enter the present national defense emergency with the advantages of a very considerable degree of scientific organization. We start with the personnel and laboratories of the educational institutions, industrial companies, and governmental bureaus, plus a large group of important scientific and engineering societies.

Next in line of organization come several agencies which were established primarily as instruments of national defense. Most important of these is the National Academy of Sciences established by an Act of Congress in the Administration of President Lincoln and charged with the duty of advising the Government on scientific matters whenever called upon to do so. Next in line comes the National Research Council established under the National Academy of Sciences by Executive Order of President Wilson in 1916—again as an instrumentality of national defense. Whereas the Academy is a limited elective body of mature and distinguished scientists, the Research Council is a widely representative body whose membership comes from all the important scientific and engineering societies and scientific bureaus. The Research Council is highly organized into functional divisions and provides a quick and ready framework for bringing to bear expert opinion or active work on any problem in any scientific field. A third special organization is the National Advisory Committee for Aeronautics established and annually financed by Act of Congress and serving as a center for the development of aeronautical science for both military and civilian purposes. This organization also dates from the time of the last war.

In spite of these very fine and valuable organizations, experience has shown a tendency to establish new organizations in each new emergency, some of these new organizations becoming permanent, as did the National Research Council and the National Advisory Committee for Aeronautics, and others being temporary for the term of the emergency as was the case with the Naval Consulting Board during the last war and the Science Advisory Board in the depression period 1933 to 1935. Now again with the threat of war on our own horizon new organizations have been established to marshal science for national defense.

SPECIAL TEMPORARY AGENCIES

The question naturally arises as to why new organizations are set up with each new emergency. Why, for example, is an organization like the National Academy of Sciences not adequate once and for all as the operating headquarters for scientific work in any national emergency? The reasons for this are, I think, fourfold. In the first place, each emergency has its own characteristics and may call for a unique type of personnel or organization. In the second place, the President of the United States is always a man of marked personality and he will have his own ideas as to how, in his capacity of Commander in Chief, he wishes to organize a war effort. In the third place, it is impossible in long periods of peace and tranquillity to maintain an alert organization of officers and staff in *any* organization, however fine its membership and its ideals. Consequently, when an emergency arises it may generally be found that the existing organization is not composed of the individuals or the interests which would seem to be most effective in handling the current situation. Finally, it is a universal law that men grow older year by year and therefore, in time of great emergency, an existing organization may not contain the youthful, vigorous, and

productive individuals who would be best qualified to handle the current problems.

For such reasons it seems to be logical, just as it has proved to be practical in experience, to establish special temporary agencies to handle the active prosecution of scientific and technological work in any great emergency and at the same time call upon such splendid organizations as the National Academy of Sciences and the National Research Council for the types of services which they are so eminently qualified to give as, for example, for wise and statesmanlike advice on scientific questions, for studies and investigations which require the co-operative effort of men selected from various fields of activity, or for organization of personnel for the handling of very large projects.

With these comments on the personnel and organization of scientists as of the time at which we entered this present war emergency, and without further comment on these established resources since they are already so generally known (except to say that they are now functioning actively and effectively in the preparedness effort), let me pass to a discussion of some of the new organizations and activities in the field of science and technology which have arisen during the past year.

NATIONAL ROSTER OF SPECIALIZED PERSONNEL

The national roster of scientific and specialized personnel is a project of the United States Government, planned to make available in one central office an index of all American citizens who have special scientific or professional skill which may be of importance to the Nation in periods of emergency and later in normal times. This is a joint project of the National Resources Planning Board and the Civil Service Commission, and the National Research Council has participated substantially in the program, which is headed by President Leonard Carmichael of Tufts College.

On a punch-card system every scientifically trained person in the country is listed with reference to his or her major professional field, with the addition of a great deal of supplementary information regarding special interests in that field, supplementary professional competence, languages read or spoken, foreign countries traveled in, previous experience in armed services or in industry, and so on. Table 1 gives the listing of this personnel in the major fields as of about June 15. The total "return" is a more accurate representation of the total scientific personnel of the country than is the total "mailed," since the mailing of questionnaires involves a considerable amount of duplication in cases of scientists who are members of more than one scientific society or other organization. The number is now probably nearly complete although returns are still coming in and, when this information was secured, it was anticipated that by July 1 the number of questionnaires mailed would have risen to about 300,000 and the number of questionnaires returned to about 175,000.

While this roster cannot, of course, give complete information about any individual, it nevertheless is proving to be extremely useful as a source of personnel for a variety of specialized jobs. In a very short time from the punched card there can be drawn a list of people who appear to fit any special condition which can be specified on the punched-card system. The organization seeking personnel can then go over this list with more refined methods in its attempt to select the particular individuals desired for the jobs at hand.

From this list more than thirty thousand names have been certified to various governmental organizations, and unquestionably the use of the roster will

be even more important in the future as the most obvious sources of scientific and engineering personnel are depleted.

The roster discloses some rather interesting and unexpected facts. For example, there are about four hundred

TABLE 1—TOTAL QUESTIONNAIRES MAILED AND RETURNED BY THE NATIONAL ROSTER OF SCIENTIFIC AND SPECIALIZED PERSONNEL

Fields	Mailed	Returned
Foreign Languages	5,849	3,552
Genetics	2,001	890
Zoology and Entomology	6,785	3,578
Physiology	865	547
Botany	1,617	1,108
Nutrition	—	—
Bacteriology, Immunology, and Pathology	3,162	1,524
Anatomy	729	585
Tropical Medicine (and Parasitology)	680	334
Chemistry	97,531	57,399
Physics and Astronomy	8,700	6,541
Mathematics	8,644	5,255
Geology	5,716	3,032
Geophysics	3,178	1,461
Actuarial Science	845	347
Speleology	334	29
Horology	1,788	336
Civil Engineering	14,051	7,670
Naval Architecture and Marine Engineering	2,070	702
Architecture	—	—
Safety Engineering	2,848	923
Transit and Traffic Engineering	611	209
Radio Engineering	4,505	2,372
Testing of Materials—Engineering and Technology	5,072	1,998
Chemical Engineering	4,666	2,453
Electrical Engineering	17,753	9,163
Mechanical Engineering	11,682	5,105
Motion Pictures—Engineering Production, Direction	261	10
Automotive Engineering	5,543	2,945
Aeronautical Engineering	5,390	3,084
Management Engineering	3,908	1,895
Heating, Ventilating, Refrigerating, and Air-Conditioning Engineering	3,542	1,772
Mining and Metallurgical Engineering and Mineral Technology	5,684	3,426
Economics	3,995	1,946
Psychology	3,748	2,937
Anthropology	902	610
History and Political Science	6,745	3,875
Personnel Administration	6,543	3,440
Speech Pathology	358	223
Statistics	3,069	1,751
Geography	1,356	642
Sociology	1,470	862
Recreation Leadership	2,287	985
Plant Pathology, Horticulture, and Agronomy	4,222	2,669
Forestry and Range Management	4,969	3,794
Animal Sciences	13,718	7,266
Total	289,392	161,245

scientifically trained people in the United States who can speak the Japanese or Chinese languages. This group is comprised largely of sons of missionaries or sons of officers of American firms operating in the Orient, or to some extent Orientals who have become naturalized citizens in the field of science. Another interesting result is the information that more American scientists have traveled in Italy than in any other foreign country, excepting Canada. A notable fact is the great preponderance of chemists.

ENGINEERING DEFENSE TRAINING

In so gigantic a program of national defense, and especially in one concerned with a warfare which has become so highly mechanized, it is not surprising that it was very quickly evident that the supply of men with an engineering type of training was very inadequate to meet the needs of the situation both in the productive industries and in the armed services. Consequently on October 9, 1940, Congress appropriated the sum of nine million dollars to be expended during that fiscal year under the United States Office of Education for the emergency training of engineers. The significance of this training program can be seen immediately from the following figures. The ordinary enrollment in the engineering schools of this country is about 110,000, and normally about 12,000 of these graduate per year. This year, of the 12,000 graduates, about 4,000 have gone into the Army or Navy, leaving a net year's output for industry of about 8,000 engineering graduates.

In the year since October 9 there have been trained, or are now in training, 125,000 people in these emergency training courses. Only in one isolated instance has there been any difficulty in the placement of those who have secured certificates from these emergency training courses and the demand for people with this training is greater now than it was a year ago. Consequently Congress has recently authorized a continuation and extension of this program during this fiscal year, raising the appropriation to sixteen million four hundred thousand dollars, and at the same time authorizing the addition of physicists, chemists, and industrial managers to the group who will be trained. This program was organized in the Department of Education under the leadership of Dean Andrey A. Potter of Purdue University and it is being carried on now under Dean Roy A. Seaton of Kansas State College.

Of the 125,000 people who have been enrolled in these special courses, about 90 per cent are young people who are already holding jobs and who are taking the work in the form of night courses to prepare themselves for more responsible positions. Of the remaining 10 per cent, a considerable number are already college graduates—for example, graduates from physics courses in liberal arts colleges who take one of these special courses to prepare themselves to work in the field of aeronautical engineering or meteorology.

During the past year, 144 engineering schools were approved for the conduct of these special courses and the total number of courses given was 2,350. An idea of the distribution of these courses and their enrollment is given in Table 2, which also has some relationship to the directions in which there is the greatest demand for additional personnel.

In this group are included about 500 women students, about 500 Negro students, and about 750 students from the armed forces. Looking to the coming year, it is evident that the number of students from the armed forces will increase very greatly and that the number of women students can also be very advantageously raised. It is also evident that there will be a very urgent demand for men trained in communication engineering, electrical physics, and radio

TABLE 2

(as of June 19, 1941)

Courses in the Field of	Total Authorized Enrollment
Aeronautical Engineering	11,125
Architectural Engineering	433
Basic Sciences	1,789
Chemical Engineering	5,674
Civil Engineering	9,427
Electrical Engineering	7,756
General Engineering (including Engineering Draftsmen)	30,352
Industrial Engineering	21,111
Marine Engineering and Naval Architecture	3,660
Mechanical Engineering	24,425
Metallurgical Engineering	6,598
Mining Engineering	242
Unclassified	1,280
Total	123,872

operation, for employment in the same general field as those for which Great Britain is now recruiting several thousand young men in this country for civilian service in Great Britain following a recent broadcast by Lord Beaverbrook on this subject.

It is very significant that such an enormous program could be put into operation with relatively little confusion and carried through so effectively by our engineering schools.

NATIONAL DEFENSE RESEARCH COMMITTEE

On June 27, 1940, the National Defense Research Committee was created by the Council of National Defense, with the approval of the President. The order specified this committee as comprising Dr. Vannevar Bush, chairman, Dr. James B. Conant, Dr. Richard C. Tolman, Dr. Karl T. Compton, Dr. Frank B. Jewett (as President of the National Academy of Sciences), Conway P. Coe (as Commissioner of Patents), one officer of the Army to be designated by the Secretary of War, and one officer of the Navy to be designated by the Secretary of the Navy. These representatives of the armed services are now General R. C. Moore and Admiral H. G. Bowen.

The order specified that

> the committee shall correlate and support scientific research on the mechanisms and devices of warfare, except those relating to problems of flight included in the field of activities of the National Advisory Committee for Aeronautics. It shall aid and supplement the experimental and research activities of the War and Navy Departments; and may conduct research for the creation and improvement of instrumentalities, methods, and materials of warfare.

Substantial funds ($6,500,000) were placed at the disposal of this committee by the President with the authority to "enter into contracts and agreements with individuals, educational or scientific institutions, and industrial organizations for study, experimental investigations, and reports."

Acting under this authorization, the National Defense Research Committee has thus far authorized 326 research contracts, of which 212 are with educational institutions and 114 are with commercial firms. The 212 academic contracts are divided among 64 educational institutions, and the 114 industrial contracts are divided among 43 commercial concerns.

The organization of the National Defense Research Committee now comprises approximately four hundred persons, exclusive of the very much larger group of scientists and engineers who are working directly on research jobs in the contracting institutions. These four hundred members of the staff are committee members, consultants, technical aides, and so forth, who are concerned with the preparation and administration of contracts, the determination of general policies and programs, and the

extensive liaison services. It is estimated that about three thousand scientists are at work on the various research projects plus a considerable number of mechanics and assistants of various types.

PROBLEMS INVOLVED

It would be exceedingly interesting, if it were proper to do so, to describe in some detail the fascinating and important problems which are engaging the attention of this committee and its associated contractors. Obviously this is not proper. Everyone involved in the program has taken a variety of oaths of secrecy, many of them have been photographed and fingerprinted, all have read and signed the Espionage Act, and every week or so another official warning comes along to remind the personnel of the importance of discretion. However, this much can certainly be said: If one thinks of the problems raised in this mechanized war—problems of protection against submarines, night bombers, or day bombers, problems of producing more effective combat weapons, problems of protection of personnel, problems of communication under difficult circumstances—one can easily imagine what are some of the items of high priority which are engaging the attention of the best scientific and engineering talent that can be assembled for the purpose.

In a general way, one can see the picture of the organization of the committee's activities from the titles of the operating divisions. To Division A is assigned the problems of armor and ordnance; to Division B, smokes, fuels, gases, explosives, and chemical problems; to Division C, communication, transportation, and submarine detection; to Division D, all other types of detection, gun controls, instruments; to Division E, the handling of patents and inventions.

Under each of the above divisions, there are a number of sectional committees each involved with some particular subject or field, and each composed of from three to twelve men headed by a chairman. These formulate the contracts, and are drawn from twenty-seven educational institutions and about an equal number of companies. All of these committee and subcommittee members serve without salary, but there are, on civil service salary, a small number of technical aides attached to division or section chairmen. To insure close co-operation with the armed services, a large group of Army and Navy liaison officers have been appointed, and the co-operation both with the armed services on the one hand and with the educational institutions and industrial companies on the other hand has been extremely gratifying. Except to say that some really significant results have already been secured and even put into production and use by the armed services, and except to say that the program has been continued for the coming year with a substantially increased Congressional appropriation, I shall comment further on only three aspects of the organizational problems.

Estimates

One of the first problems was to estimate the amount of money which could be effectively used for research work within the fields designated by the Executive Order and in the period of one year. Estimates were made on a variety of bases, such as comparing the probable order of magnitude of the job with the size of the operations in a great university or industrial research laboratory. However, the estimate which eventually proved to be by far the most accurate was based upon the number of scientific and engineering research men who might reasonably be expected to be available for work on national defense problems. The committee made its best estimate as

to this number and then took the figure $5,000 per technically trained research worker as representing about the average total cost of operation of a research organization (this figure was secured from a survey of industrial research made by the National Resources Planning Board). This estimate led to approximately ten million dollars for the first twelve months of operation—a figure which experience showed to be just about right. For the second year's operations, with increased mobilization of personnel and increased pressure for research and development problems, the appropriation should be considerably larger than this amount.

Reimbursements

A second organizational problem was to determine the proper basis for reimbursement of educational institutions or industrial organizations which undertake research work on contract with the National Defense Research Committee. The basic principle was immediately agreed upon that the work should be done without either financial gain or financial loss by the contracting institution. The real problem therefore was to determine a reasonable and simple basis of putting this principle into effect. For educational institutions, an analysis was made of the expenditures by a large number of typical universities and engineering schools in the conduct of their normal educational and research operations. Two aggregate figures were secured. The first figure represented the total expenditures made for the direct prosecution of the educational or research effort. This aggregate sum included teaching and research salaries. The second aggregate sum represented the direct and indirect overhead and included all salaries of administrative officers, grounds and buildings maintenance, heat, light, power, library, infirmary or hospital service, and insurance. In comparing these two aggregate sums, it was found surprisingly typical of educational institutions that the total overhead sum thus defined amounted to a little over 50 per cent of the total direct operating expense for salaries. Consequently, the committee decided that a suitable basis for contract with educational institutions would be by payment of all direct expenses for salaries, wages, and equipment, plus an overhead allowance to the institution amounting to 50 per cent of the total salary and wage items. A similar study of industrial organizations indicated that this overhead charge should be more nearly 100 per cent of the aggregate labor item, since industrial organizations have all the expenses of educational institutions plus taxes and interest on capital investments. Therefore, 100 per cent of the labor item was adopted as a standard for overhead in contracts with industrial organizations.

Patentable inventions

A third problem of policy had to do with the handling of patentable inventions which may be made during the course of the research supported by Government funds through the National Defense Research Committee. Here again, a simple basic principle was immediately arrived at, namely, that the Government should have royalty-free rights to use any such inventions in connection with the requirements of its armed services. However, in putting this basic principle into effect, some very difficult and complicated situations have to be met, particularly in relations with industrial organizations which may already possess a very large patent structure in the field concerned. It would obviously be impossible to expect these companies to accept the contract for a relatively small amount of research work which might result in forcing the company to donate to the Government practically its entire

background of previous research and invention in the field. However, a standard contract was finally arrived at which included a patent clause, as well as the arrangement concerning overhead, payments, reports, obligations, and so forth, which has met with practically universal acceptance and consequently all contracts with the National Defense Research Committee are drawn as closely as possible on the basis of this standard form.

OFFICE OF SCIENTIFIC RESEARCH AND DEVELOPMENT

On June 28, the President by Executive Order established the Office of Scientific Research and Development under the directorship of Dr. Vannevar Bush, president of the Carnegie Institution of Washington, and including an advisory council consisting of the director as chairman, the Chairman of the National Advisory Committee for Aeronautics, the Chairman of the National Defense Research Committee (in which position President James B. Conant now replaces Dr. Bush), the Chairman of a newly established Committee on Medical Research, a representative of the Army, and a representative of the Navy.

This new office is established within the Office for Emergency Management of the Executive Office of the President and includes within it the National Defense Research Committee and the new Committee on Medical Research, each of which will have its funds for operation.

The powers of this new office in the field of scientific research and development are very significant, as suggested by the following paragraphs quoted from the Executive Order:

> Advise the President with regard to the status of scientific and medical research relating to national defense and the measures necessary to assure continued and increased progress in this field.
>
> Serve as the center for mobilization of the scientific personnel and resources of the nation in order to assure maximum utilization of such personnel and resources in developing and applying the results of scientific research to defense purposes.
>
> Co-ordinate, aid, and where desirable supplement the experimental and other scientific and medical research activities relating to national defense carried on by the Departments of War and Navy and other departments and agencies of the Federal Government.
>
> Develop broad and co-ordinated plans for the conduct of scientific research in the defense program in collaboration with representatives of the War and Navy Departments; review the existing scientific research programs formulated by the Departments of War and Navy and other agencies of the Government and advise them with respect to the relationship of their proposed activities to the total research program.

The inclusion here of an operating committee to conduct medical research, as required by national defense, brings to fruition a program in medicine parallel to that of the National Defense Research Committee in the physical sciences, of which the need has been realized but in which organizational complications and overlapping of interests have hitherto prevented accomplishment. This Committee on Medical Research, which is now in process of formation in accordance with the Executive Order, consists of a chairman and three members to be appointed by the President and three other members to be designated respectively by the Secretary of War, the Secretary of the Navy, and the Administrator of the Federal Security Agency. These latter three members are to be selected from the respective staffs of the Surgeon General of the Army, the Surgeon General of the Navy, and the Surgeon General of the Public Health Service, with particular reference to their qualifications in the field of medical research.

With this organization of the Office of Scientific Research and Development, there is established, for the first time in our history, so far as I know, a scientific research agency in the high councils of the Federal Administration, set up so as to co-ordinate and operate in the interests of national defense through all Government and private agencies and implemented with adequate funds and authority to perform significantly.

CONCLUSION

This report is necessarily inadequate and incomplete and it undoubtedly shows a certain lack of proportion because of the fact that I have of necessity treated more at length those aspects of the problem on which I am best informed.

To any of you who would wish to supplement these remarks by independent reading, I would most highly recommend that you read all or part of the report of the National Resources Planning Board dated December 1940 on the subject, "Research—A National Resource. II. Industrial Research." This is available for the price of one dollar from the Superintendent of Documents, Washington, D. C. It is an extraordinarily illuminating document showing the status and trend in industrial research. One of the interesting and encouraging comments made by the distinguished committee which carried through this survey is the suggestion that it is not inconceivable that within forty years as many as one million research workers may be employed in United States industry. I think perhaps you would find of most interest and enlightenment Section V on the subject of research abroad, particularly the section dealing with research in Germany. This report on research in foreign countries will serve to give us a sense of proportion in evaluating our own accomplishment or lack of accomplishment, and the section on Germany will be found to be of particular interest with reference to the present war situation.

Karl T. Compton, Ph.D., D.Sc., Dr.Eng., LL.D., has been president of Massachusetts Institute of Technology since 1930. Prior to that he was research professor and head of the department of physics of Princeton University. During the last war, he was Associate Scientific Attaché to the American Embassy in Paris. During the early years of the recent depression, he served the Government as chairman of the Science Advisory Board and member of the Business Advisory Council. At the present time he is a member of the National Defense Research Committee, chairman of the New Products Committee of the New England Council, and chairman of the Advisory Committee on Scientific Research of the National Association of Manufacturers.